



Hydrogen from Coal

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U.S. Department of Energy

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Purification Technologies**

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Presentation Outline

- **Hydrogen Initiatives**
- **Hydrogen from Coal Central Production Goal**
- **Why Coal**
- **Why Hydrogen Separation Membranes**
- **Coal-based Synthesis Gas Characteristics**
- **Technical Barriers**
- **Targets**
- **Future Plans**

The Hydrogen from Coal Program Supports the Hydrogen Fuel Initiative and FutureGen

FutureGen

Gasification

Fuel Cells

Turbines

**Hydrogen
from
Coal Program**

**Hydrogen
Fuel Initiative**

**Carbon Capture
& Sequestration**

- The Hydrogen Fuel Initiative is a \$1.2 billion RD&D program to develop hydrogen production, storage, delivery, and utilization technologies
- FutureGen is an integrated sequestration and hydrogen research initiative to test advanced technologies in a world-scale co-production plant
- Hydrogen from Coal Program will coordinate with associated DOE programs in Gasification, Fuel Cells, Turbines, and Carbon Capture & Sequestration



Production Goal for Hydrogen from Coal

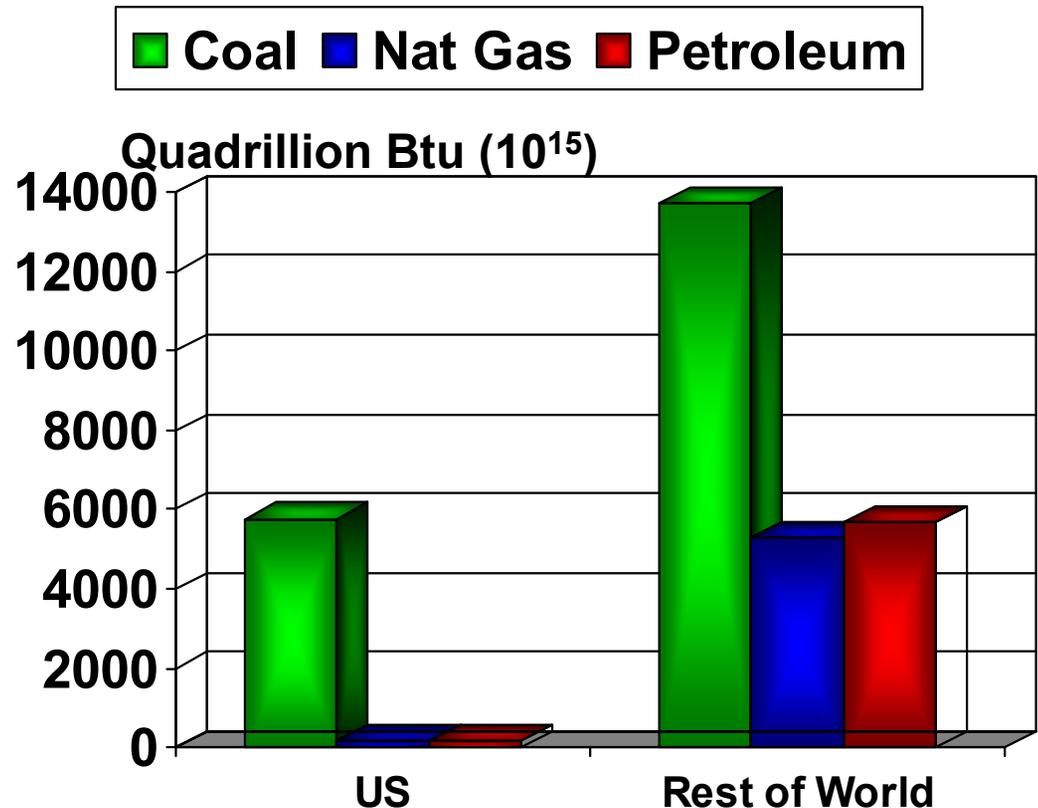
- **Central Pathway: By 2015, demonstrate a 60 percent efficient,^(a) near-zero emissions, coal-fueled hydrogen and power co-production facility that reduces the cost of hydrogen by 25 percent compared to current coal-based technology.**

(a) Based on equal quantities of coal used to produce hydrogen and electricity

Why Hydrogen From Coal?

- Huge U.S. coal reserves
- Hydrogen can be produced cleanly from coal
- Coal can provide large, affordable quantities of H₂
- Sequestration technology will remove CO₂
- Bridge to renewable H₂ production

Fossil Energy Reserves (a)



(a) Proved oil and gas reserves, and recoverable coal reserves

Summary of Hydrogen from Coal Cases

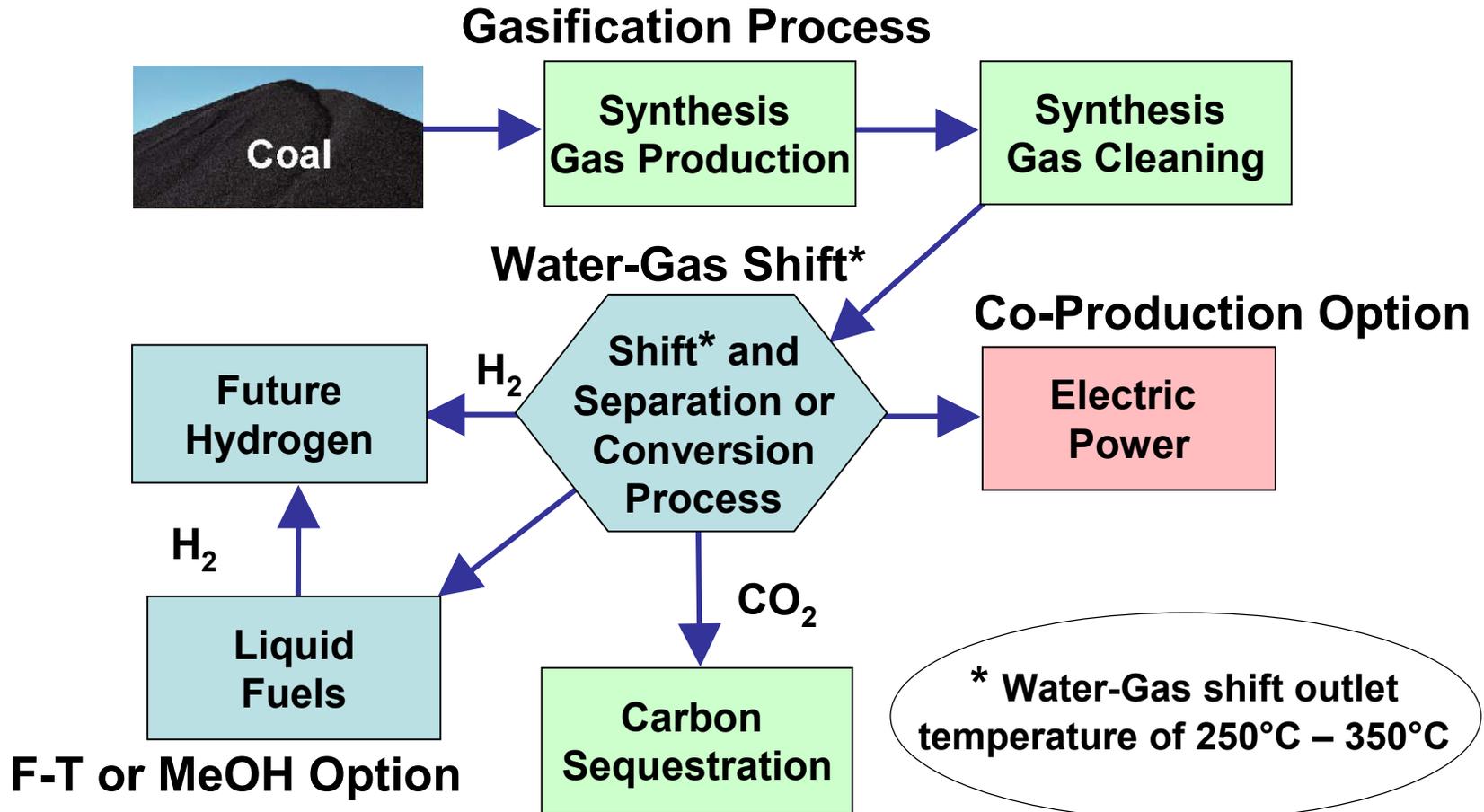
	Case 1	Case 2	Case 3
Gasifier*	Conventional	Advanced	Advanced
Separation System	PSA	Membrane	Membrane
Carbon Sequestration	Yes (87%)	Yes (100%)	Yes (100%)
Hydrogen Production (MMSCFD)	119	158	153
Coal (TPD) as received	3000	3000	6000
Efficiency (%) (HHV basis)	59	75.5	59
Excess Power (MW)	26.9	25	417
Capital (\$MM)	417	425	950
RSP of Hydrogen (\$/MMBtu) / (\$/kg)	8.18 / 1.10	5.89 / 0.79	3.98 / 0.54

* Conventional gasification technology assumes Texaco quench gasification; advanced gasification technology assumes advanced E-gas gasification.

- RD&D is estimated to reduce the cost of hydrogen from coal by 25%.
- Co-production of hydrogen and electricity (5.36 ¢/kWh) can further reduce the cost of hydrogen production by 32%.

Source: Hydrogen from Coal, Mitretek Technical Paper MTR 2002-31. July 2002.

Hydrogen is Cleanly Produced from Coal through Gasification



IGCC Plants provide the option for efficient hydrogen production with the ability to co-produce electricity and clean liquid fuels.

Synthesis Gas Properties Derived from Coal in comparison to Natural Gas

- Coal-produced synthesis gas has more contaminants (S, Hg, NH₃, HCl) prior to clean-up
- Synthesis gas from coal is CO-rich, and from natural gas is H₂-rich
- System integration of H₂ separation technology into coal gasification facility is more complex
- Goal is to combine/eliminate process steps such as synthesis gas cleaning, WGS, and separation into one membrane – coal requires a more robust process than natural gas

Membrane Systems Barriers

- **High cost**
- **Low selectivity**
- **Low flux rates**
- **Do not operate at optimal process temperatures**
- **Intolerance to impurities in hydrogen from coal**
- **Undesired atomic rearrangement**
- **Scale-up required**
- **Thermal cycling**
- **Lack of seal technology and materials**
- **Defects during fabrication**
- **Lack of demonstration of novel technologies**
- **Complex process designs**

Hydrogen Separation – Technical Targets

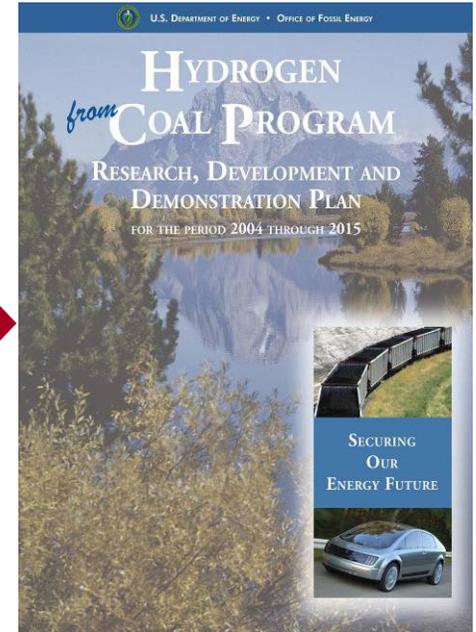
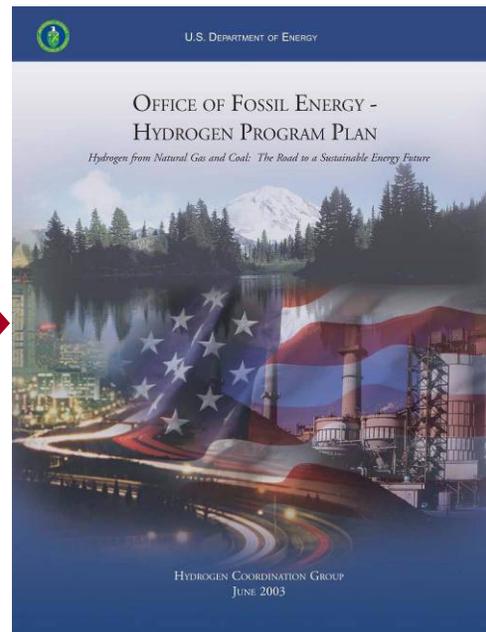
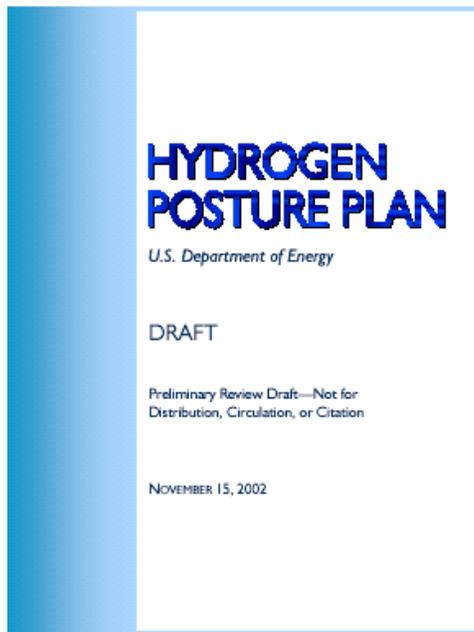
Performance Criteria	2007 Target	2010 Target	2015 Target
Flux scf/h/ft ² @100 psi ΔP H ₂ partial pressure & 50 psia permeate side pressure	100	200	300
Operating Temp, °C	400-700	300-600	250-500
S tolerance	Yes	Yes	Yes
Cost, \$/ft ²	150	100	<100
WGS Activity	Yes	Yes	Yes
ΔP Operating Capability, system pressure, psi	100	Up to 400	Up to 800 to 1000
CO tolerance	Yes	Yes	Yes
Hydrogen Purity	95%	99.5%	99.99%
Stability/Durability (years)	3	7	>10

From Office of Fossil Energy *Hydrogen from Coal RD&D Plan*, June 10, 2004 - DRAFT

Future Plans - Hydrogen from Coal RD&D Program

- **Continue research on advanced membranes for hydrogen separations**
- **Initiate co-funding research with EERE on hydrogen membrane separations**
- **Initiate pre-engineering scale module development**
- **Systems analysis**
 - **Expand analysis to include a wider range of hydrogen from coal production pathways based on promising research results**
 - **Look at other promising membrane systems**
- **Initiate study of other separation systems**

FE Hydrogen Program Plan and Hydrogen from Coal RD&D Plan



***Hydrogen from Coal – Clean, Secure,
Affordable Energy for the Future***

<http://fossil.energy.gov/programs/fuels/>